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INTERPRETABILITY OF REMOTE SENSING* IMAGES FOR URBAN FEATURES
Yogyakarta Example

by
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ABSTRACT

Urban features change very rapidly due to quick urbanization, especially for developing countries. It creates a problem for city planners and administrators as terrestrial method of surveying and mapping always lags behind to provide recent and accurate data on urban features. No wonder that remote sensing technology is called for in this respect.

In adopting remote sensing technology, however, there is a problem whether it will be better to use airborne or spaceborne remote sensing. The airborne system is beneficial for the better spatial resolution, whereas the multitude benefit of the spaceborne system is in the better temporal resolution; both of which are badly needed to provide urban features appropriately. The main objective set in this stage of research is to study the interpretability of both systems, using manual and digital methods.

In the manual interpretation, the smallest area feature which is recognizable is 8x ground resolution for air photo, 5 pixels for color composite Landsat image (MSS + TM), and 1 pixel for SPOT image of extremely good example. For linear features, it is 0.3 ground resolution, 0.6 pixel, and 0.5 pixel respectively.

INTRODUCTION

Urban features are generally more complex as compared to the rural ones so that better spatial resolution is required in this respect. To say it another way, aerial photograph is more appropriate to provide urban features. As viewed from the rapid

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change of the urban features, however, satellite data is better due to the better temporal resolution. Luckily that the spatial resolution of satellite data progresses very well within these last four decades. It progresses from 1,000m, 100m, 10m, into 1 m from the 1960s, 1970s, 1980s, into 1990s respectively; or, ten times each decade.

Fundamental research is necessary to be carried out in order to find out the appropriate use of each type of remote sensing data in providing urban information. It is the main objective of this research which is written in the article. Yogyakarta city is taken as the study area due to the availability of relatively complete remote sensing data.

MATERIAL AND METHOD

The available remote sensing data which are used in this study are listed below.

1. Colour panchromatic photo of 1980, scaled at 1 : 1,000
2. Black and white panchromatic photo of 1972, scaled at 1 : 6,000
3. Black and white panchromatic photo of 1959, scaled at 1 : 7,500
4. Black and white panchromatic photo of 1996, scaled at 1 : 13,000
5. Colour infrared photo of 1981, scaled at 1 : 36,000
6. Colour composite Landsat MSS image of 1972, blown-up into 1 : 250,000 and 1 : 125,000
7. Colour composite of Landsat TM of 1994, scaled at 1 : 250,000
8. Black and white SPOT image of 1987, panchromatic mode, blow-up into 1:100,000 and 1:50,000
9. Digital data of Landsat TM of 1994

The interpretability of each type of remote sensing data is studied separately with mostly manual method of interpretation. The digital interpretation is just a start in this stage. It will be dealt with further in the later stage of the research, waiting for more digital data which is being ordered. It is likely to cover the one meter resolution of satellite data as well, which is still in negotiation.

The manual interpretation is adopted on the original scales and on the enlarged ones. Indeed the enlarged scale will not inercase the spatial resolution, but the enlarged features may increase the interpretability into a certain extent.

LITERATURE REVIEW

Quick Urbanisation

As calculated based on the amount of urban population in 1950 and the predicted amount in the year 2,000, great differences occour between cities in the developed and the developing countries. New York as the biggest city in the world in

1950 had an amount of 12.3 millions people; it increases into 16.8 millions in 2,000. London as the second biggest city had 8.7 millions people and it increases into less than 11.7 millions people in the same period. It means an increase of 37% for New York and 35% for London within a period of 50 years. Mexico City on the other side, increases from 3.1 millions people into 25.6 millions (726%) and Jakarta from less than 2.6 millions into 13.7 millions (427%) for the same period (UN Urban Agglomaration Chart 1990, in Elo et al., 1996). It means that the increase of urban population can be much better controlled in the developed countries. The urban features can be much better arranged accordingly. It is an indication that the adoption of remote sensing technology to provide urban information is easier to carry out in the developed countries as compared to the developing ones. It should be kept in our mind in using remote sensing for urban study.

Interpretability

As stated by Sabins (1997), *detectability* is the ability of an imaging system to record the presence or absence of an object, whereas *recognizeability* is the ability to identify an object on an image. The term *interpretability* which is used in this article comprises detectability and recognizability based on Sabins terminology.

Sabins (1997) stated further that there are no quantitative measures for detectability and recoqnizability, and hence, for interpretability. To the writer's opinion, *interpretability of an object* (Io) is greatly affected by the *spatial resolution* (Rs) of the remote sensing system, the *contrast ratio* or *contrast* (Rc), the *environmental complexcity* (Ce), the *interpreter's ability* (Ai), and the *image scale* (Si), the functional equation of which can be framed as follows:

$$\mathbf{Io = f\,(Rs, Rc, Ce, Ai, Si)} \qquad \mathbf{(1)}$$

Spatial Resolution

Spatial resolution of a sensor is a limit on how small an object on the earth's surface can be and still be seen by a sensor being separate from its surroundings (Lillesand and Kiefer, 1994).

Sabins (1997) defines spatial resolution as the ability to distinguish between two closely spaced objects on an images, or the minimum distance between two objects at which the image of the objects appear distinct and separate. Both definitions indicate that spatial resolution is also a measure on how detail a sensor system can provide information.

Doyle (1975) stated that up to the sixties remote sensing images were mostly recorded on film. Afterwards, however, electronic recording was introduced and it is getting more common today. Consequently, there are two ways to express the spatial resolution and there should be a method of conversion for both expressions.

Spatial resolution for photographic images are stated in *line pair per milimeter (Lp/mm)* in the image and in *meter per line pair (Rm/Lp)* on the ground. The former is called *image resolution* whereas the latter is called *ground resolution*.

Image resolution is a reflection of film quality. Images resolution of 25 lp/mm for instance, means that the film can record 25 lines per milimeter, including the spaces between the lines, all of which are of equal size (width). It will also mean that one line pair occupies a space of 0.04 mm in the image, or 2 meter in the ground for aerial photograph scaled to 1 : 50,000. An image resolution of 60 lp/mm is much better than that of 25 lp/mm.

The terms lines per milimeter or line pairs per milimeter are used inter-changeably with similar meaning. It is also the case with resolving power and spatial resolution in term of image resolution, the latter of which has slightly different application. While resolving power applies to an imaging system or a component of the system, spatial resolution applies to the image produced by the system (Sabins, 1997; Lillesand and Kiefer, 1994; Slater, 1975).

Spatial resolution for data recorded electronically is stated in meter *per pixel (Rm/pixel)*. Pixel is picture element, a very small cell containing certain spectral value, the size of which is in the order of 50 μm (Lillesand and Kiefer, 1979).

Doyle (1975) formulated the following conversion for both expressions of spatial resolution.

Photographic recording **Electronic recording**

$$\textbf{Rm/lp} = \textbf{k x Rm/pixel} \qquad \textbf{(2)}$$

where:

Rm/lp = Resolution in meter on the ground per line pair in the photo
Rm/pixel = Resolution in meter per pixel on the ground
k = coefficient of conversion which has two values, i.e.:
k = 2.8 for high contrast image (3:1)
k = 4 for low contrast image (1.6:1)

Spatial resolution is affected by a number of factors. Sabins (1997) stated that spatial resolution is affected by *the shape, size, arrangement*, and *contrast ratio* of the object. The writer of this article agrees with Sabins's statement, by adding some other factors, such as *scale, wavelength used, and band width of the electromagnetic spectrum*. One more factor is likely to be added particularly for photographic system, i.e.: *film type*. Each factor is briefly described below.

Concerning the shape, every reader having sufficient experience in image interpretation will fully agree that linear features are much easier to detect and to recognize, even for objects of less than one pixel size. A highway of some 20 meters wide for example, it is faintly discernable in the Landsat MSS image of 80 meter pixel size, especially in areas of high contrast. It is an example of shape and contrast which affect spatial resolution

The size of object also affects spatial resolution. Small, medium, and big cities result different spatial resolution.

Regarding the arrangement, settlement with regular pattern of housing will produce better spatial resolution than the settlement of irregular pattern. As far as the scale is concerned, image of larger scale will produce better spatial resolution, or more detail information.

About the wavelength used may need to refer the quantum formula as follows:

$$Q = \frac{hc}{\lambda} \tag{3}$$

where :

Q = energy of a quantum, Joules (J)

h = Planck's constant, 6.626×10^{-34} J sec

c = speed of the electromagnetic radiation, 3×10^{8} m/sec

λ = wavelength of the electromagnetic spectrum, μm

The energy of a quantum is inversely proportional to its wavelength. The shorter the wavelength, the stronger is the energy which consequently produces better spatial resolution (Lillesand and Kiefer, 1994).

The band width which is used in the system of recording also determines the spatial resolution. It stems from the fact that wider band in the same wavelength will mean stronger energy and better spatial resolution accordingly. The spatial resolution of SPOT image is a very good example in this respect. Although SPOT - XS and SPOT - P are recorded with similar wavelength and with the same scale, the spatial resolution is 10m for SPOT - P and 20m for SPOT - XS.

Film type affects greatly the spatial resolution of photographic image. Although two series of airphotos are recorded with the same scale and with similar wavelength and bandwidth, the airphotos which are recorded with film of fine texture (*slow film*) have higher resolution than those which are recorded by film of coarse texture or *fast film* (Curran, 1985).

Spatial resolution is greatly affected by contrast, as stated by Lillesand and Kiefer (1994). This statement can be charted in table 1.

Table 1. Grey tone and the contrast

Gray tone	Contras			Spatial resolution
	High	Medium	Low	
Dark	///////////////			High
Dark grey		///////////////		Medium
Medium grey			///////////////	Low
Light grey		///////////////		Medium
Light	///////////////			High

Source : Tabulated from Lillesand and Kiefer, 1994

Table 1 indicates that two objects which look dark grey and light grey in the image of medium contrast, they will look with extreem dark and light in high contrast image and they may look medium grey in the low contrast image. The spatial resolution will differ accordingly.

Lillesand and Kiefer stated further in quantitative manner that resolution is strongly affected by contrast, i.e.: (1) at a contrast ratio of 1.6 : 1, a given panchromatic film may have resolving power of 50 lp/mm, and (2) at contrast ratio at 1,000 : 1, the same film may have resolving power of 100 lp/mm.

Contrast

Contrast is an abbreviation of *contrast ratio* or *contrast difference* (Slater, 1975). *Contrast ratio* (C_R) is the ratio between the brightest and the darkest parts of the image (Sabins, 1977) and it is defined as :

$$\mathbf{C_R = \frac{B\ max}{B\ min}} \quad \mathbf{(4)}$$

where:

B max is the maximum brightness of the scene
B min is the minimum brightness of the scene

It may also mean the ratio between the brightness of an object and the surrounding (Lillesand and Kiefer, 1994).

Slater (1975) stated four types of contrast as follow:

Contrast ratio : $\mathbf{C_R = E\ max/E\ min}$ **(5)**
Differential contrast : $\mathbf{C_D = (E\ max - E\ min)/E\ min}$ **(6)**
Logarithmic contrast : $\mathbf{C_L = Log\ 10\ (E\ max - E\ min)}$ **(7)**
Modulation : $\mathbf{M = (E\ max - E\ min)/(E\ max + E\ min)}$ **(8)**

where E max and E min equal to B max and B min of Sabins respectively. It is the contrast ratio which is dealt with in this article.

Contrast is classified differently by different scientists, i.e.:

a.	High contrast	:	CR = 3 : 1
b.	Low contrast	:	CR = 1.6 : 1 by Doyle (1975), and

a.	High contrast	:	CR = 9/2 = 4.5
b.	Medium contrast	:	CR = 5/2 = 2.5
c.	Low contrast	:	CR = 3/2 = 1.5 by Sabin (1977)

It is Sabins classification which is used in this article, with the low contrast ranging from 1.5 to 1.6.

The influence of contrast to spatial resolution is reflected well in formula 2 where the coefficient of conversion is as small as 2.8 for high contrast image and as big as 4 for the lower one.

Contrast is a function of a number of factors which can be framed as follow:

$$\mathbf{C_R = f(To, L_W, T_f, Do)} \tag{9}$$

where:

To = type of object
Lw = wavelength used
Tf = film type
Do = object density

Contrast depends heavily on the type of object, because each object has particular reflectance. Just taking three objects as examples, black asphalt reflects 2% of the solar radiation, concrete 36% and snow 80%. Cleared asphalt highway passing through snowy ground will produce much higher contrast as compared with light concrete highway passing that area (Estes, 1974).

Every object has a unique spectral characteristics, as shown in Figure 1. For those five objects, the contrast will be higher at 0.9 µm wavelength. At 0.5 µm, the contrast between four objects is very low. It is an indication that the wavelength contributes significantly for the contrast.

Film type in term of Gamma also determines the image contrast. Gamma is expressed with a slope formed by delta density devided by delta log exposure. Other factors being the same, the higher the Gamma, the higher the contrast of film (Lillesand and Kiefer, 1994).

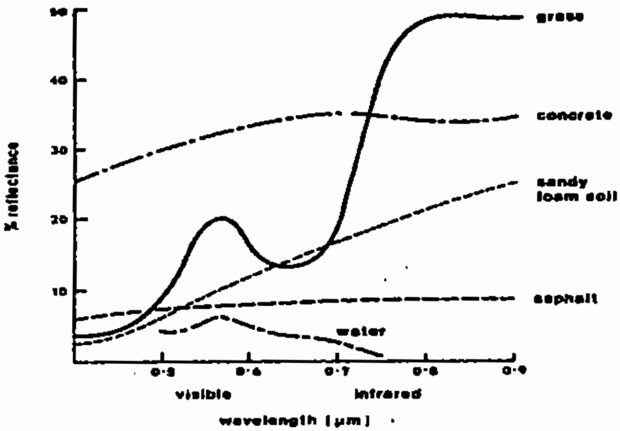

Figure 1. Spectral reflectance curve for selected features (Kennie and Matthews, 1985)

Regarding the contribution of object density to film contrast, the findings of Welch (1982) is noteworthy to refer. Welch examined the relative size of urban built-up areas for cities of 50,000 to 500,000 population in United States and Canada, Europe, and Asia, as presented in table 2.

Table 2. Relative size of urban built-up areas of 50,000 to 500,000 population, and relative building density per unit area

Country	Relative sizes	Approximate relative building density per unit area	Category
United State	1.0	1.0	1
Canada	0.60	1.6	1
Sweden	0.15	6.6	2
Japan	0.11	9.1	2
China	0.03	33.3	3

Source : Welch (1982), with slight modification

The relative building density or the spatial frequency affects the contrast significantly, as seen in Figure 2.

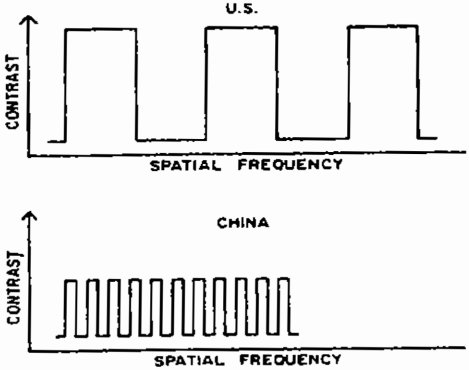

Figure 2. Spatial frequency and contrast of urban environment of the United States and China (Welch, 1982)

Figure 2 indicates that contrast is about twice greater in USA as compared with China. It means that for urban features in China needs much better resolution than for urban features in USA and Canada.

Based on his study on urban areas in five countries, Welch (1982) stated that parcel in USA can be identified with satellite image having 80 m pixel, whereas for China needs a pixel size of 5 m (Figure 3).

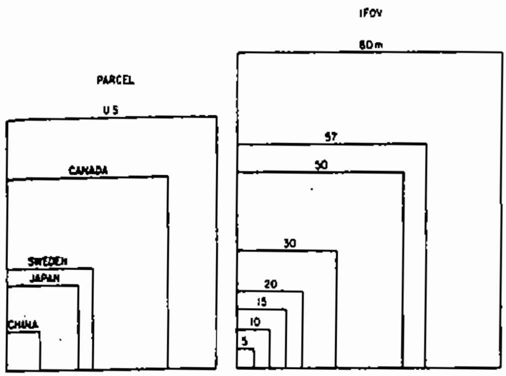

Figure 3. Comparison of pixel size to identify urban parcel in five countries (Welch, 1992).

The writer of this article does not agree with Welch's idea in this respect, especially for cities in Indonesia. There are two reasons underlying this disagreement;

first, what we can see in large scale airphoto is just plot of land, and plot of land does not always mean parcel which has something to do with legal right. The second reason is that many parcels are less than 100 m^2 which are covered by dense building, which are quite unlikely to be discernable, even in remote sensing image of 1 m pixel size or its equivalent.

One more interesting finding to refer from Welch is the spatial resolution requirement for urban landuse in USA based on Anderson's classification (Figure 4).

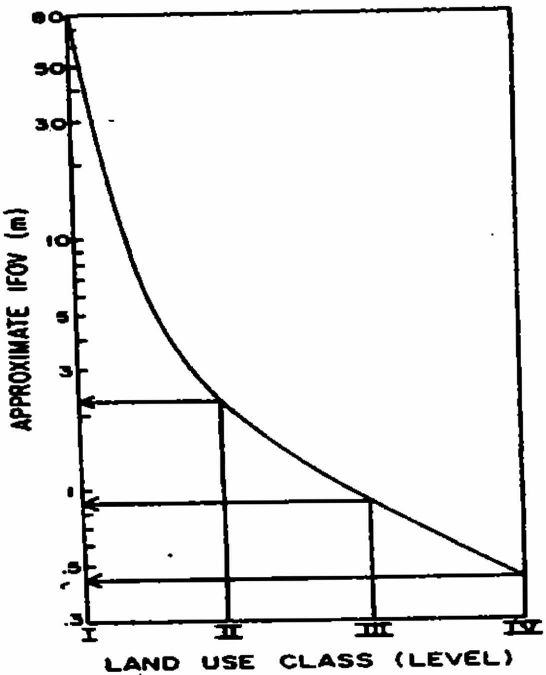

Figure 4. Resolution as a function of the mapping requirement for Levels I - IV land use classes in USA based on Anderson et al. (Welch, 1982).

At least three important points can be drawn from figure 4, i.e:

1. For urban land use in USA, pixel size of 80 m can adopted for land use class *level I*. It can be used to differentiate urban and rural land use and also to delineate its boundary line. In the case of Indonesia, however, indeed Landsat MSS can be used to differentiate urban and rural land use, but to delineate the boundary line is quite unlikely.

2. The spatial resolution requirement drops drastically from 80m to less than 3m for land use *class I* into *class II.*
3. With the availability of *1m resolution satellite data* in this decade, land use class up to *level III* may be interpreted from that satellite data. For Indonesia, however, the greatest possibility is only up to *level II.*

Environmental Complexity

Welch has described clearly the influence of building density (or spatial frequency) in forming different contrast, which consequently influences the interpretability. Environmental complexcity, however, is not touched yet. Urban features in the developing countries are not only characterized by higher building density, but also by more complex appearance due to more heterogenety. It causes the interpretability more difficult. It means that not all which can be done with remote sensing in cities of the developed countries can be applied in the developing countries as well. Similar work may be adopted as far as the latter applies remote sensing system with better spatial resolution.

Interpreter's Ability

Interpreter's ability play a great role in interpretability. It includes individual ability on one side and sufficient training and experience on the other side. Concerning the individual ability, Lo (1986) stated that it is determined by *general*, *local*, and *speefic level of reference*. The *general level of reference* is the interpreter's general knowledge of the phenomena and processes to be interpreted. The *local level of reference* is the interpreter's intimacy with the local environment. The *specific level of reference* is the interpreter's deeper understanding of the processes and phenomena he or she wants to interpret.

Image Scale

It has been stated before that image scale is a determinat factor for spatial resolution, and hence for interpretability. What is meant by image scale here is also including the enlarged scale. Indeed the spatial resolution remains the same, but the enlarged size of features may increase the interpretability.

Assuming the smallest object that can be interpreted on an enlarged photograph (of 50 line pairs per mm) is 1 mm square or 1 mm in diameter, and that it must have high contrast with the surroundings, and the photograph is at least of 7 line pairs per mm, then the smallest objects that should be interpretable at various photo scales and the enlargements are presented in table 3.

Table 3. Smallest objects that can be interpreted for various photo scales and the enlargements

Original Scale	Enlargement					
	2x	3x	4x	5x	6x	7x
1 : 1,000	0.5 m	0.25 m	0.25 m	0.2 m	0.17 m	0.14 m
1 : 10,000	5.0 m	3.3 m	2.5 m	2.0 m	1.7 m	1.4 m
1 : 25,000	12.5 m	8.3 m	6.25 m	5.0 m	4.2 m	3.5 m
1 : 50,000	25.0 m	16.7 m	12.5 m	10.0 m	8.3 m	7.0 m
1 : 100,000	50.0 m	33.0 m	25.0 m	20.0 m	16.6 m	14.0 m

Source : Sutanto and Forster, 1997.

One thing is worth to note regarding scale enlargement, that is, the image quality is getting worse for greater enlargement. Consequently, the enlargement can only be done into a certain limit. Doyle (1975) defined the limit for useful scale enlargement as follows:

$$\mathbf{E = 0.1\ Rp} \qquad \mathbf{(10)}$$

where:

E = useful enlargement factor
Rp = photographic resolution

Assuming an image resolution of 50 lp/mm, the useful enlargement will be 5 times. With an assumption that the smallest object which can be interpreted is 1 mm square, it means 1 m on the ground for an airphoto scaled at 1 : 1,000. In the five times enlargement then the smallest object which can be interpreted is 0.2 m on the ground.

What has been discussed so far is about the interpretability of remote sensing data for urban features. Accuracy of the result, however, is of notable importance to discuss. We are thinking of two types of accuracy, i.e.: *interpretation accuracy* and *mapping accuracy*.

Interpretation Accuracy

Remote sensing is a relatively new technology which develops very rapidly. It is used widely for various purposes in numerous fields. Many things can be done with remote sensing, but question which is often raised is 'what about the accuracy of the result of interpretation'. It is logical question because inaccurate result may aim to a wrong direction. Accuracy test should be accomplished accordingly.

Accuracy test can be carried out in two ways, i.e.: accuracy test of the parameter and accuracy test of the final result.

Parameter accuracy

Let us take an example of using remote sensing to evaluate the quality of slum settlement. Some parameters are commonly used, i.e. : building size, building lay out or regularity, terrain quality, etc. (Socki, 1993). Remote sensing is used to estimate these parameters, the accuracy of which is tested to each parameter before it is synthesized to evaluate the slum area. Tolerable accuracy is commonly set out in advance, for instant 90%, 85%, etc. These parameters are adopted to the evaluation if only they reach the tolerable accuracy.

Accuracy of result

With the use of the foregoing example, the result of evaluating the quality of the slum settlement is carried out. The result is usually compared with the truth, which can be a map or the formal record. The users will use the result as far as the accuracy is acceptable, as otherwise they will unhappily reject it.

Mapping Accuracy

Map should be accurate to provide spatial data, or data on the surface of the earth with good position based on grid system. It is the only best way to present spatial distribution and spatial analysis as well. The accuracy is getting more significant because maps are used in geographic information system which is lately adopted elsewhere. Regarding map accuracy, Doyle (1984) is of the opinion that it includes accuracy in term of *content, position*, and *elevation*. Maling (1989) stated that map accuracy comprises three points, i.e. : *quantitative accuracy, qualitative accuracy*, and the *completeness of the qualitative* or *the content accuracy*.

Map accuracy is measured with the closeness of points in the map with the correct position. It is usually tested on a number of points in sample area using the National Map Accuracy Standard (NMAS). Maling (1989) pointed out two methods of testing the accuracy, i.e. : *the ten percent accuracy* and *the root mean square error*.

The ten percent accuracy

An acceptable accuracy is assigned in this method, position as well as elevation accuracy. The tolerable accuracies are :

0,85 mm error of position for maps of 1 : 20,000 or larger
0,50 mm error of position for maps of less than 1 : 20,000
0,5 countor interval error of elevation for maps of all scales

Several points may have error larger than this assigned ones, the amount of which may not exceed 10% of the total amount of points being tasted. Hence, it is called ten percent accuracy.

The root mean square error

The map accuracy is measured as follows :

Horizontal accuracy :

$$\textbf{RMSp} = 5.7 \times 10^{-4}\ \textbf{Sm for maps of 1 : 20,000 or larger} \quad \textbf{(11)}$$
$$= 3.4 \times 10^{-4}\ \textbf{Sm for maps of less than 1 : 20,000} \quad \textbf{(12)}$$

where :

RMSp = Root Mean Square Planimetric error in meter
Sm = Scale of the map

Vertical accuracy :

$$\textbf{RMSh} = \textbf{0.34 C.I} \quad \textbf{(13)}$$

where :

RMSh = Root Mean Square Error of height in meter
C.I = Contour interval

For *A class* military map, the standard used is similar to NMAS; and for *B class* military map, the error may be twice that amount. Topographic map adopts A class military map, whereas cadastral map needs even higher accuracy.

Mapping accuracy is, however, of greater concern for cartographer to prepare more accurate maps (land titling, civil engineering works, infrastructures, etc.). For thematic information such as land use, population density, environmental quality, etc., consideration is more concentrated on the qualitative accuracy or content accuracy, with less emphasis on metric accuracy (Kennie and Matthews, 1985).

Spatial Resolution and Map Scale

The result of interpreting remote sensing data is generally presented in maps of various types and scales. In order to attain the required accuracy, each map scale should be supported by certain spatial resolution of the remote sensing data.

Doyle (1975) stated that human eyes are able to observe an image with a minimum spatial resolution of 6 lp/mm, or 7 lp/mm after Forster (1977). In order to compensate the quality decrease in the process of printing, images are generally made with 10 lp/mm resolution. It means that each line occupies a space of 0.1 mm and the ground resolution will be 0.1 mm x the map scale. Based on this idea, Doyle in 1975 made a formula for the spatial resolution requirement to prepare maps of certain scales, as follows:

$$\mathbf{Rg = Sm \times 10\text{-}4} \tag{14}$$

where :

Rg = Ground resolution in meter per line pair
Sm = Map scale

In 1984, however, Doyle created another formula in this respect. Assuming a reasonable compromise of 10 pixels/mm, he defined the following formula :

$$\frac{\mathbf{1mm}}{\mathbf{10\ pixel}} \times \frac{\mathbf{1\ m}}{\mathbf{1{,}000\ mm}} \times \mathbf{Sm = Rp}$$

$$\mathbf{Sm = 10{,}000\ Rp} \tag{15}$$

$$\text{or}\quad \mathbf{Sm = 4{,}000\ Rlp} \tag{16}$$

where:

Sm = Map scale
Rp = resolution in meter per pixel
Rlp = resolution in meter per line pair

It means that for a final map scaled to 1 : 24,000 should be supported by a ground resolution with a pixel size of 2.4 m; and a pixel size of 25 m for a final map of 1 : 250,000. This is meant to attain both quantitative and qualitative accuracy of the map. With this in mind and also concerning the requirement for map accuracy, Doyle (1984) provided the following table.

Table 4. Requirement for image map series

Scale number	Resolution		Position	Contour	Elevation
	Rm/lp	Rm/pixel	δp (m)	interval (m)	δe (m)
1 : 1,000,000	250	100	300	100	30
1 : 500,000	125	50	150	50	15
1 : 250,000	63	225	75	25	8
1 : 100,000	25	10	30	20	6
1 : 50,000	12,5	5	15	10	3
1 : 25,000	6,3	2,5	7,5	5	1,5

Source : Doyle, 1984

Just as an example, if we mean to prepare a final map of 1 : 100,000, it has to be supported by remote sensing image with a pixel size of 10 m or finer, the conversion of which is 25 m/lp. The standard deviation in position is 30 m and the smallest contour interval is 20 m. If elevation is to be depicted on the map, the standard deviation in elevation is 6 m. For Indonesia, however, we use to define a contour interval of 1/2000 x the map scale in meter.

What has been stated by Kennie and Mattews is of notable importance in this case. Although working map should be made with larger scale than the final map, large scale air photos can be used in the reserve, still with good accuracy. Very large scale air photos can be used to provide final maps up to six times greater in term of it's scale, as seen in table 6.

Table 6. Photographic scale, ground resolution, and scale of the final map

Photographic scale	Ground resolution @ 40 lp/mm	Flying height (m)		Mapping scale	Enlargement Factor (photo:map)	Contour Photograp interval
1 : 3000	0.075 m	450	→	1 : 500	6 x	0,5 m
1 : 5000	0.125 m	750	→	1 : 1000	5 x	1 m
1 : 10000	0.25 m	1500	→	1 : 2500	4 x	2 m
1 : 25000	0.625 m	3750	→	1 : 10000	2.5 x	5 m
1 : 50000	1.25 m	7500	→	1 : 50000	1 x	10 m
1 : 80000	2.0 m	12000	→	1 : 100000	0.8 x	20 m

Source : Kennie and Mattews, 1985

Air photos scaled to 1 : 3,000 can be used to prepare final map of 1 : 500 because of it's very fine resolution, meaning an enlargement of six times instead of reduction.

THEORETICAL BASIS

The interpretability of an object covers detectability and recognizability of that object as stated in formula 1. The conversion of spatial resolution from photographically recorded images into digital ones follows formula 2.

Out of the four types of contrast stated by Slater, it is the contrast ratio which is framed in formula 5 which is used in this article. The term contrast ratio or contrast is used interchangeably with similar meaning. Contrast is determined by type of object, the wavelength used, film type, and object density as stated in formula 9. Regarding the spatial resolution requirement to provide urban information, cities in Indonesia need better spatial resolution as compared with cities in the developed countries for similar works.

The enlarged scale does not increase spatial resolution, but it increases the interpretability into a certain extent due to the enlarged features. The enlargement factor is limited by 0.1 multiplied by photographic resolution as depicted by formula 10.

Accuracy of the result of image interpretation includes interpretation accuracy and mapping accuracy. Interpretation accuracy comprises parameter accuracy and accuracy of the result. Mapping accuracy covers quantitative accuracy (metric or position and elevation accuracy) and qualitative or content accuracy, including the correctness and completeness of objects to be mapped. For quantitative accuracy, National Map Accuracy Standard Stated in formula 11, 12, and 13 are used. For metric accuracy is, however, more the concern for precise cartographic work. For other works, concern is more on the accuracy of the content with less emphasis on metric accuracy. It is the latter which is used in article. Nevertheless, the spatial resolution requirement to prepare maps of certain scale which is given in formula 15 and 16 are conequently followed.

RESULTS AND DISCUSSION

The result which is discussed in this article is the result of the first year work of the University Research for Graduate Education entitled "Remote Sensing for Urban Study and Land Use Planning". Unfortunately, most of the first year was spent for the acquisition of remote sensing data so that not much which can be written in this occasion. The first year work was mainly aimed to investigate the interpretability of urban features on various remote sensing image of different scales, manually as well as digitally.

Manual Interpretation

The primary objective of the manual interpretation is to interprete the smallest urban features which are recoqnizable on various types and scales of image. Some examples are presented in this article.

1. True Color Photographs Scaled to 1:1,000, 1980

Assuming an image resolution of 40 lp/mm, the ground resolution of this photo is 0,025 m/lp. Theoretically, the smallest features which can be identified is several times that size. In practice, however, as there are many factors which define the smallest features being discernible, this interpretability will vary. The following axamples may confirm this statement.

1.1 Linear feature of 15 cm wide (Location 1 in figure 5)

It was a white metallic plate covering the join between the bridge and the asphalted road, the length of which was about 15 m. It was very easilty identified through the very bright tone on dark-grey background. This feature was located on the bridge near the office of Public Health in Kyai Mojo street which does not exist anymore now.

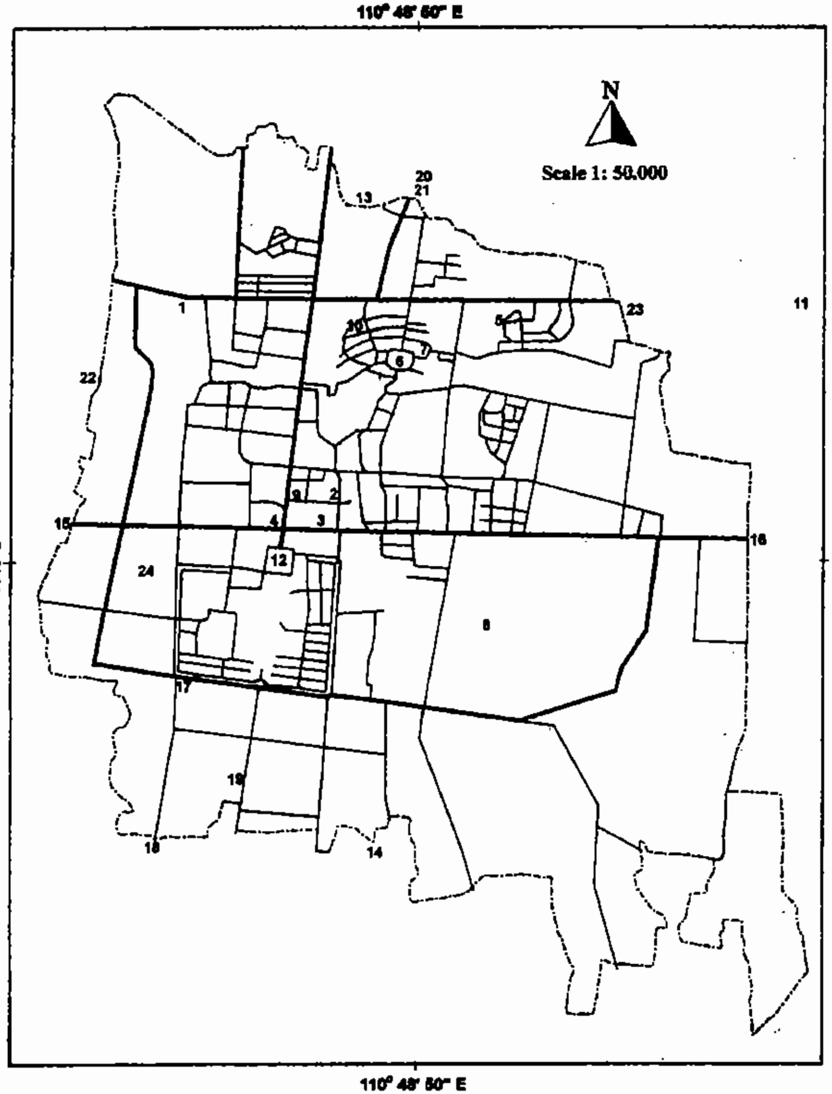

Figure 5. Location of the points for field check

1.2 Partition of building under construction (Location 2)

Wall partitioning the building under construction was identified easily because it was not roofed yet. The walls were made of brickstone, the thickness of which was 12 cm before it was cemented. They appeared as grey lines on dark background.

1.3 White lines on parking lot (Location 3)

Newly painted lines partitioning the parking lot in the shopping centre was very easily identified as very bright lines on the grey background. The width of the lines were around 10 cm. Based on this clear lines we were able to see whether or not the parking was well arranged.

1.4 Other features (Location 4)

Becak differs from bikes based on it's size and form. Bikes, however, do not differ from motor cycles in their appearance. Outomobile, station wagon, and bus can be identified very easily due to their form and size. Even for the vehicles of the same size, bus can be differentiated from truck due to the uniformity of their color. It is also the case for pick-up and station wagon.

2. Pancromatic Black and White Airphotos of 1 : 6,000, 1971

The ground resolution is 15 cm per line pair for image resolution of 40 lp/mm. Some examples of the result of interpretation are given below.

2.1 Tennis field (Location 5)

Tennis field can be identified very easily based on :

form : a rectangle

size : ± 16 x 34 cm, measured on the wire fences

association: surrounded by wire fence which is discernible through the shadow. The size of the wire is some 2 mm and the iron frame is 3 cm, less than 15 cm. Fortunately the shadow helps much to identify it, supported by linear form which frequently makes the identification much easier. The edge lines and the partition lines (5 cm) are another association adding prominent characteristics of the tennis field.

2.2 Kridosono stadium (Location 6)

The smallest feature of the stadium which can be identified with great ease is the wall fence surrounding the stadium. The thickness of the wall is 30 cm, or twice this spatial resolution, but it looks quite well basing on the shadow. This wall defines significantly whether or not the square is a stadium.

Another smallest features identified in this photo is the net of the football square, the site of which is in the center of the back line. It can be recognized with care through the shadow, the size, and the site. Although the size of the net rope is much less than 1 cm, far less than the ground resolution, the shadow and the site share a great deal in the identification.

2.3 The tower of the Office of Telecommunication (Location 7)
The size of the tower frame is less than 10 cm, but it appears reasonably clear through it's shadow.

2.4 Other features

a. Small vessel of 1.2 x 4.8 m (Location 8)
It appears distinctly due to the form, the size and the grey tone on the dark background.

b. Roof layout and roof from (Location 9)
The roof layout may form a square, a retangle, or a combination of more than one form. The roof form may be the so called kampung, limas (pyramid), or any other form,

c. All asphalted road network are discernible, unless those which are covered by trees or building. Because road is usually a straight line, the hidden part can be extrapolated from the clear ones.

A trial was made to blow up the scale twice and four times. Two expections stimulated this trial; first, the smallest feature which was recorded on the film might be easier to identify if scale is made larger and second, the possibility to delineate and plot it on the map might be greater. Unfortunately, however, the quality of the photo is not good because it is only a reproduction of the photo print so that the decreased quality of the blown-up photo caused the increase of information from the enlarged photo is not significant. The result may differ if the quality of the original photo is good, and the scale enlargement is carried out from the original film (it is not easy to reach the original film due tue a very tight restriction). In that case, the decreased quality of the enlarged one may by still reasonable.

3. Black and White Panchromatic Photo of 1 : 13,000, 1996
Assuming an image resolution of 40 lp/mm, the ground resolution should be 32,5 cm per line pair.

3.1 Roof layout and roof form (Location 9)
Being viewed stereoscopically, roof layout and roof form are identified with reasonably ease. Anyhow, the roof appears as a sloping plane sheet without relief, whatever it is made of.

3.2 Upper roof of mosque (Location 10)

An upper roof of mosque with a size of 2.6 x 2.6 m can be identified. It is much larger than the spatial resolution

3.3 Other features

Road network are discernible, but vehicles are not

Again an effort was made to blow it up 2.5 so that the scale becomes 1:5,200; and also 5 times enlargement so that the scale becomes 1:2,600. The outstanding example on the increase of interpretability is that in the 2.5 enlargement (1: 5,200) the roof which appears as a sloping flat plane in the original scale, appears with ridges making parallel lines of 18 cm apart to each other in the field. The height differences in the field is 3.5 cm. The clear parallel ridges with certain distance and height direct the interpreter to conclude that it is tile roof, or asbestos roof made in tile form. The parallel ridges appear much clearer in the 5 times enlargement (1:2,600). The quality of the photo, however, decreases considerably. The result of manual interpretation on the aerial photographs are presented in table 6.

Table 6. Interpretability of several objects on airphotos of various type and scales

Type and scale of airphoto	Type of object	Ratio to the ground resolution	Contrast	Interpretability
Coluor panchromatic photo, 1:1,000	=White metallic plate, 15cm x 15m	6:1	High	1
	=Partition wall, 12cm x 30cm, unroofed	5:1	High	1
	=Partition lines on parking lot, 10cm x 300cm	4:1	High	1
Black and white panchromatic photo 1:6,000	=Partition line of tennis field, 5 cm	0.3:1	High	2
			Medium	1
	=Wall fence around stadium, 30cm thick, 3m high	2:1	Medium	2
	=Net of the football square, 8mm, 2m high, 5m long	19:1	Medium	3
	=Telecommunication tower 8cm, 12m high	1:2	-	5
Balck and white airphoto 1:13,000	=Parallel ridges on the roof, 3,5cm high, 18cm apart, 8m long	0.24:1	Medium	2
Ditto, scale is enlarged 2.5 times	=Ditto	0.24:1	medium	1
Ditto, scale is enlarged 5 times	=Ditto	0.24:1	Medium	3
Ditto	=Type of the roof			

The writer tries to define the interpretability as the following

1 = object is detectable and very easily recognized based on image characteristics (stadium, railway station, traditional market place)
2 = object is detectable and easily recognized based on image characteristics, Fieldcheck is necessary for confirmation (hospital, well planned school building, large graveyard)
3 = object is detectable but recognition based on image characteristics is doubtful. Fieldcheck is compulsory in this respect (bank, church, post office)
4 = object is detectable but recognition based on image characteristics is unlikely to do (sport building, garage, clinical building).
5 = object is not detectable (drainage channel, small parcels with dense building cover, indoor parking lot). Information is attained wholly from the field or other sources. Because such information can not be acquired through remote sensing technology, but it is definitely needed for some purposes, object of category 5 is better to be plotted in the process of tabulation

The increase of the interpretability of blown-up scales in table 6 is of notable importance to discuss. The interpretability of the parallel ridges improves from *5* in the original scale into *2* in the 2.5 times enlargement and into *1* in the 5 times enlargement. Because the ridge pattern and size characterize the type of roof, the interpretability of the roof type improves from *5* (not recoqnizable) into *3*. The improvement of interpretability of roof type depends largely on whether or not ridge pattern and size characterize it, and on how far the interpreter knows this characteristics. For objects without having such characteristics, at least the detectability will increase in the enlarged scale.

4. Color Composite Landsat MSS Image, 1972

The ground resolution or the pixel is 80 m. At first the image of 1 : 250,000 was used, then it was blown up into 1 : 125,000 and 1 : 62,500. Regarding the image quality, it is quite likely that a blow up until 1 : 125,000 is the maximum as far as it is carried out photographically. The enlargement until 1 : 62,500 produces blurred features on the image.

Observing the 1 : 250,000 image, the location and the extent of Yogyakarta urban area can be identified through the greyish colour, with reasonable contrast from the country side. On the image of 1 : 125.000, outstanding features such as the Adisucipto airport (± 125 pixel), the Kridosono stadium (± 5 pixel), the front square of the castle (± 9 pixel), and the Code river running north-south in the mid of the city (less than I pixel wide) can be identified with care. The local knowledge surely support in this respect. The difference between physically urban features and the country side appears clearly, but, it is hard to delineate the urban features or even it is quite unlikely to do.

On the 1 : 62,500 image, features become larger in size but more difficult to identify due to blurred appearance.

5. Color Composite Landsat TM Imagem 452, 1994

The best TM digital data in term of the least cloud cover which was acquired from LAPAN was recorded in July 1994. A colour composite was made by assigning red for band 4, green for band 5, and blue for band 2. The appearance of the physical urban features differs greatly to the country side as the former looks bluish green, whereas the latter looks mostly red. The appearance of some small features is presented in Table 7, together with color composite Landsat MSS image of 1972.

Table 7. The interpretability of several small objects on color composite Landsat MSS and Landsat TM of Yogyakarta city

IMAGE TYPE AND SCALE	OBJECT					
	Type	Appearance	Ratio to pixel size	Contrast	Interpre tability	Location
Color composite Landsat MSS, 457	=Adisucipto airport	Very light red with black straight line	125:1	Medium	2	11
	=Runway	Dark line	0,8:1	High	1	11
	=Golf course	Long red lines with lighter background	63:1	Medium	3	11
	=Kridosono stadium	Light retangle with smooth coner	5:1	Medium	3	6
	=Palace square	Light square	9:1	Medium	3	12
	=Code River	Long dark line, irregular form	0.7:1	Medium	3	13-14
Color composite Landsat TM, 452	=Mainroad	Straight line, dark blue	0.6:1	High	1	15-16
	=Road	Straight line, dark blue	0.24:1	High	2-3	17-18
	=Kridosono stadium	Light square, rounded conner	25:1	Medium	2	6
	=Palace square	Light square	44:1	Medium	2	12
	=Football square	Light rectangle	13:1	Medium	3	19
	=Urban forest	Red rectangle	6.6:1	Medium	3	20
	=Adisucipto airport	Light long rectangle	125:1	High	1	11
	=Runway	Straight line, dark blue	0.8:1	High	1	11
	=Central University building, UGM	bluish green rectangle	5:1	Medium	3-4	21

6. Black and White SPOT Image, Panchromatic Mode, 1987

The original scale is 1 : 400,000 with a pixel size of 10 m. The scale was enlarged into 1 : 100,000 and 1 : 50,000

On the image of 1 : 100,000, the difference between urban and rural areas look more distinctly. Still is hard to demarcate visually the sharp boundary line of the physical urban area.

All features which can be recognized in the Landsat MSS and TM colour composites can be recognized in the SPOT image with greater ease. Besides, some features which are not recognizable in the former, can be recognized in the latter, Terminal building in the airport, airplane parking ground and railway are some examples.

One outstanding example can be given here. Two trees which are planted in the mid of the castle square, each of which is surrounded by wall fence of 10 m square or just one pixel size, can be recoqnized well. It is due to the high contrast, because there are only two trees in the square of around 200 m x 200 m, making a lighter and homogenous background. This feature is not recognizable in the Landsat colour composites. The interpretability of some small urban features is presented in table 8.

Table 8. The interpretability of some small objects on black and white SPOT panchromatic mode, 1987 Yogyakarta city

TYPE	OBJECT				
	Appereance	Ratio to pixel size	Contrast	Interpretability	Location
Main road	=Straight line, medium grey	2 : 1	Medium	2	15-16
Road	=Straight line, medium grey	0.6 : 1	Low	3	17-18
Railway	=Straight line,sharp join, smooth bending, medium grey	0.5 : 1	Medium	2-3	22-23
Kridosono stadium	=Light square, rounded corner	225 : 1	High	2	6
Palace square	=Light square	400 : 1	High	1	12
Two specific trees in the centre of the palace square, wall fenced each	=Dark grey dot on light =background	1 : 1	High	1	12
Football square	=Light rectangle	120 : 1	High	1	24
Urban forest	=Dark rectangle	60 : 1	Medium	2	20
Adisucipto airport	=Long rectangle, light grey	1125 : 1	Low	1	11
Ranway	=Straight line,dark grey	2.5 : 1	Medium	1	11
Terminal building	=Dark rectangle	40 : 1	High	2	11
Airplane parking lot	=Light grey rectangle	90 : 1	Medium	3	11
Central University building, UGM	=Four solid buildings forming rectangle with open space inbetween, medium grey	54 : 1	Low	3	21
Physical boundary of urban-rural area	=Difference in building density	-	Low	3	-

Based on table 6,7, and 8, at least 6 important points can be noted as follow.

1. The interpretability of small area features needs several times the ground resolution of the image. It is unlikely to figure it because interpretability is determined by a number of factors.
2. In general we can say that the finer the resolution, the better the interpretability. This statement works well assuming other factors being equal. In the case of road for instance, the interpretability is *2* to *3* for Landsat TM colour composite, and it is 3 for blcak and white SPOT image. The interpretability of the former is a little bit better instead of worse because of the better contrast.
3. Although area feauters require several times the pixel size to be recognizeble, the two trees in the mid of the castle square render an interpretability of *1* due to the high contrast. It is an indication that contrast plays a great role in determining the interpretability.
4. The enlargement of photho scale in table 6 helps a great deal in improving the detectability of the ridge pattern and its size on the roof. Because ridge pattern and size characterize the roof type, the latter is recognizable in the blown-up scale.
5. It has been widely accepted that even for linear features of smaller size than the ground resolution, it is usually interpretable in favourable condition. In the case of airphotograph, parallel ridges of 0.25 ground resolution is recognizable. It is 0.3 pixel size, 0.24 pixel size, and 0.6 pixel size for Landsat MSS, Landsat TM, and SPOT image respectively for this linear features.
6. Wire fence around the tennis field is recognizable although it is 0.03 the ground resolution. It is not only the size of the wire which determines the interpretability in this case, but also the cumulative appearance of numerous wires supported by the height (4m) which casts shadow and the linear features which improves the interpretability.

Digital Interpretation

This interpretation was carried out using the digital data of Landsat Thematic Mapper (TM)of July 1994. For the meanwhile the interpretation is aimed to identify urban land cover of Yogyakarta and the surrounding area based on three methods, i.e.: *box classification*, *nearest neighbour*, and *maximum likelihood*; each of which using supervised classification. The program which was used was ILWIS (Integrated Land and Watershed Management Information System) version 1.4. Moreover, it is also aimed to compare the result of this three classifiers which were used in this process.

The procedure of classifying digital data follows the concept of Lillesand and Kiefer (1994). The training stage was first established, followed by digital classification based on the pixel clustering of the Landsat TM digital data of band 5,4 and 2 which had been geometrically and radiometrically corrected. Three earlier stated calssifier were then adopted to classify each cluster of pixel based on training stage, for the purpose of identifying the land cover type. Filter edge enhancement was adopted for each band to enhance the contrast of the demarcation of objects. Linear stretching was adopted as well in order to enchance linear features.

The result of classification are nine types of land cover as follow:

1. open space with shrub on it
2. asphalted road
3. agricultural crop, mainly rice of medium density
4. agricultural crop, mainly rice of high density
5. built-up area, mainly settlement
6. open space, dominated by dry land
7. mixed vegetation on moist soil
8. built-up area and moist soil
9. mixed vegetation of medium density

Comparing those three classifiers, box or parallelepiped classifier is the simplest and hence the fasted, the rapidity of wich is then followed by maximum likelihood and nearest neighbour respectively. As viewed from the amount of unclassified pixels, the sequence is the reserve. The nearest neighbour classifier leaves the least amount of unclassified pixel, followed by the maximum likelihood and the box or parallelepiped classifier respectively (table 9).

Table 9. Difference of unclassified pixel based on the three classifiers

TYPE OF CLASSIFIER	UNCLASSIFIED PIXELS (%)
Box or parallelepiped	25
Maximum likelihood	16
Nearest neightbour	9

An accuracy test of classification will be verified later based on Lillesand and Kiefer's method (1994), as seen in table 10.

Table 10. Error matrix resulting from training set pixel

	Training Set Data (Known Cover Types)						
	W	S	F	U	C	H	Row Total
W	480	0	5	0	0	0	485
S	0	52	0	20	0	0	
F	0	0	313	40	0	0	72
U	0	16	0	126	0	0	353
C	0	0	0	0	342	79	142
H	0	0	38	0	60	359	459
Column							481
Total	480	68	356	248	402	438	1992

Producer's Accuracy	**User's Accuracy**
W = 480/480 = 100%	W = 480/485 = 99%
S = 052/068 = 76%	S = 052/072 = 72%
F = 313/356 = 88%	F = 313/353 = 87%
U = 126/248 = 51%	U = 126/42 = 89%
C = 342/402 = 85%	C = 359/481 = 74%
H = 359/438 = 82%	H = 359/481 = 75%

Overall accuracy = (480 + 52 + 313 + 126 + 342 + 359) / 1992 = 84%

Source : Lillesand and Kiefer, 1994

CONCLUSION

The conclusions which are drawn in this article are not the final ones, as the research is still underway. Some works concerning the interpretability of remote sensing data are still in the process. Interpretability of scanned photograph, comparison of interpretability between three cities (small, medium, and big cities) and the digital classification are being carried out as a fundamental research to help the magister and the doctorate students studying urban area.

The following are conclusions which can be drawn for the time being.

1. The smallest urban feature which is interpretable is generally several times the spatial resolution for area feature. It is difficult to define the exact figure as the interpretability varies with the spatial resolution, the contrast ratio, the environmental complexity, the interpreter's ability, and the image scale; assuming the interpretation is applied to remote sensing image of similar good quality.
2. Area feature of one pixel size having high contrast is recognizable on SPOT image. Wall fence forming a square of 10 m x 10 m is a good example in this case. The recognizability is, however, not only determined by the high contrast, but also by the interpreter's knowledge on the special characteristics of the object. This is the smallest object of area feature which is interpretable in this research.
3. For linear feature, the interpretability is applicable for objects of less than one ground resolution. The interpretability differs from object to object and from one image to another image. In the case of parallel ridges in the airphoto of 1 : 13,000

which is enlarged twice and four times, one fourth of the ground resolution is recognizable. It is 0.3, 0.24, and 0.6 pixel size for other linear features in the Landsat MSS, Landsat TM, and SPOT-P respectively.

4. In the case of partition lines of a tennis field in the airphoto of 1 : 6,000, the interpretability reaches one third of the ground resolution. For the wire fence of 3mm diameter or 0.02 ground resolution, it is also regognizable particularly through the shadow. It is the smallest object recognizable in this research. The interpretability is, however, not only based on the size, but it is more based on the cumulative appearance of numerous wires supported by linear feature casting the shadow.
5. The enlargement of photo scale helps to improve the detectability of parallel ridges very significantly. Objects which are not observable in the original scales, emerge very clearly in the enlarged scales. More importantly, roof type is then recognizable based on the characteristics in term of parallel ridge pattern and size. It is thought to be valid for other objects having certain characteristics known to the interpreter.
6. Regarding the rapidity of digital classification, it starts from box or parallelepiped classifier which is followed by maximum likelihood and nearest neighbour respectively. Concerning the unclassified pixels, the sequence is the reverse.

REFERENCES

Curran, P.J., 1985, *Principles of Remote Sensing*, Longman Scientific & Technical Harlow.

Doyle, F.J., (Aut-Ed), 1975, Carthographic Presentation of Remote Sensor Data, In: *Manual of Remote Sensing vol.II*, Reeves, R.G., Anson A., and D. Landon (Eds.), American Sociaty of Photogrammetry, Falls Church, Firginia.

Doyle, F.J., 1984, Surveying and Mapping with Space Data, *ITC Journal No.4*, Enschede.

Elo, O., Palm, E., and L. Vrolijks, 1996, Disaster Reduction in Urban Area, *ITC Journal No.1,* Enechede.

Estes, J.E., 1974, Imaging with Photographic and Nonphotographic Sensor Systems, In : *Remote Sensing Techniques for Environmental Analysis*, Estes J.E. and L.W. Senger : Eds., Hamilton Publishing Company, Santa Barbara, California.

Foster, B., 1997, Introduction to Resolution and Interpretation of Air Photographs, *Lecture Notes*, URGE Project - Remote Sensing for Urban Study and Land Use Planning, Faculty of Geography, Gadjah Mada University, Yogyakarta.

Maling, D.H., 1989. *Measurements from Maps, principles and methods of cartometry,* Pergamon Press, Oxford.

Kennie, T.J.M and M.C. Matthews, 1985, *Remote Sensing in Civil Engineering*, Surrey University Press, Glasgow.

Lillesand, Th.M and R.W. Kiefer, 1994, *Remote Sensing and Image Interpretation*, John Wiley & Sons, Inc., New York.

Lo, C.P., 1986, *Applied Remote Sensing*, Longman Scientific & Technical, Harlow.

Sabins, F.F., 1997. *Remote Sensing: principles and interpretation*, W.H. Freeman and Company, New York.

Slater, Ph.M., 1975, Photographic System for Remote Sensing, In : *Manual of Remote Sensing Vol. I,* Reeves, R.G., Anson, A., and D, Landon: Eds., American Society of Photogrammetry, Falls Church, Virginia.

Socki, B.S., 1993, The Potential of Aerial Photos for Slum and Squatter Settlement Detection and Mapping, *Asian-Pacific Remote Sensing Vol.5 No.2,* January 1993, Bangkok.

Sutanto, 1997, The Interpretability of Remote Sensing Images for Urban Features, Yogyakarta examples, *Paper presented at the one day workshop on Urban Study*, July 2, 1997, Yogyakarta.

Sutanto and B. Forster, 1997, Interpretability of air Photographs and Satellite Images for Urban Studies, *Proceedings of The 18th Asian Conference on Remote Sensing*, 20-24 October 1997, Kuala Lumpur.

Welch, R., 1982, Spatial Resolution Requirements for Urban Studies, *International Journal of Remote Sensing, Vol.3 No.2*, London.